Maize-Nutrient-Manager

Use and data collected in 2019-20 season

(Songwe region Tanzania)

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Submission date: 17 December 2020

(D-17623-2)

NWO-GCP4 Scaling Readiness of Nutrient Management project
in collaboration with the Crop Nutrient Gap Project

The '**NWO-GCP4 Scaling Readiness of Nutrient Management**' project (full title: 'Scaling readiness of climate smart, nutrient management decision support tools in different institutional environments (Tanzania and Ethiopia)' project is a 3-year project funded by the Global Challenges Programme (GCP, 4th call) of the Netherlands Organisation for Scientific Research (NWO-WOTRO) and the Crop Nutrient Gaps project.
The project is a collaboration between the Knowledge, Technology and Innovation group of Wageningen University, the Bill & Melinda Gates Foundation funded Taking Maize Agronomy to Scale in Africa (TAMASA) project of the International Maize and Wheat Improvement Centre (CIMMYT), and the Crop Nutrient Gap project.

The Crop Nutrient Gaps project (full title: Bringing Climate Smart Agriculture practices to scale: assessing their contributions to narrow nutrient and yield gaps) is funded by CGIAR-CCAFS (Climate Change, Agriculture and Food Security), Wageningen University & Research, the International Fertilizer Association (IFA) and Yara (in-kind), and collaborates with CIMMYT and University of Nebraska-Lincoln. It runs from 2016-2021.

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Andersson, J.A., M. Kilakila., R. Hijbeek, 2020. **Use and data collected in 2019-2020 season, Songwe region, Tanzania**. Wageningen University. 17 p.
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This work was implemented as part of the CGIAR Research Programs on Climate Change, Agriculture and Food Security (CCAFS), which is carried out with support from CGIAR Fund Donors and through bilateral funding agreements. For details please visit https://ccafs.cgiar.org/donors. The views expressed in this document cannot be taken to reflect the official opinions of these organizations.

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Summary

The provision of more tailored fertilizer management advice to smallholder farmers critically hinges upon – largely lacking – field-level management data, as management is key to efficient fertilizer use. The **Maize-Nutrient-Manager (MNM)** mobile phone application collects of such data at scale, and directly converts this data into actionable advice for the farmer.

This data document describes the data collected with the MNM application (n=1038 records) in the Songwe region in Tanzania in the 2019-2020 season. In addition, this report provides information on the data collected through farmer Advice Forms (AF) one which the MNM advice was written. As these forms were simultaneously used by farmers as Field Records (FR) of in-season management practices, these forms constitute another source of data (n=723).

This report presents some descriptive statistics on MNM use and management practices in the 2019-20 season, but due to an incomplete data collection process (partially caused by COVID-19 travel restrictions), cannot present extensive analyses of the data collected. Analyses that can identify major yield determining factors and impacts of MNM use will be conducted in 2021, when 2019-20 yield data has been collected through the deployment of MNM (in November and December 2020) just before the start of the 2020-2021 season.

1. Introduction

This report provides an overview of data collected with the **Maize-Nutrient-Manager (MNM)** advisory tool for field-specific nutrient management advice for smallholder maize growers, the in 2019-20 season. MNM is an application for service providers (currently, agricultural extension workers) and smartphone owning smallholder farmers. It generates field-specific nutrient management advice, based on the farmer's current management practices. The aim of this field-specific advisory tool is to help smallholder maize growers to systematically record their practices, and to enhance the use efficiency of the fertilizers they can afford to use. The focus on farmers' management, their available resources and nutrient use efficiency, increases the use-base of field-specific fertilizer advisory as unlike other forms of advice, resource-constrained farmers are no longer prompted to invest more capital and labour – which they may not have – in order to increase profitability and production. Thus, field-specific advice becomes actionable for large numbers of farmers – both the financially powerful, and the financially constrained. In addition, the MNM application's focus in improving nutrient use efficiency helps to reduce nutrient losses, particularly N_2O emissions that are associated with unbalanced NPK use.

While MNM is an advisory tool for field-specific nutrient management advice, it is simultaneously a learning system for farmers, knowledge service providers and researchers. It alerts knowledge service providers and farmers to systematically record those field conditions and management practices that are most likely to be relevant for increasing nutrient use efficiency. These field-specific records of management practices, as well their outcomes (yields) constitute the main data source for the identification on nutrient use efficiency (NUE) enhancing practices, and subsequently, fields-specific advice messages. A first preliminary analysis of MNM's impact on NUE among a small subset of advised and non-advised farmers suggests that farmers who received MNM advice had a higher NUE in the 2019-20 season (Kilakila, 2020).

This document is organized as follows: First, in chapter 2, we give a brief overview of MNM use and user statistics in the 2019-20 season, including figures on numbers of trained users and the types of advices they provided. Chapter 3 provides an overview of the MNM-dataset (n=1038) and presents some descriptive statistics on field conditions of the MNM advice fields, as well as fertiliser use, crop management practices and yields of those farmers who also cultivated maize on their MNM advice field in the 2018-19 season (n=340).

Chapter 4 gives an overview of a second dataset (n=723), that is, the management data as recorded by the advised farmers themselves, during the 2019-20 season. This data was collected through the Farmer Advice Forms. Extension workers had handed these forms, with the copied MNM-*app* advice written on it, to the MNM farmers upon advice provision. The flipside of these forms is a short record book which the farmers records actual management during the maize growing season

2. MNM users and use statistics

2.1 MNM-Users: Government extension workers in Momba and Mbozi district

In November and December 2019, just before the start of the maize growing season, 33 government extension workers were trained in the use of MNM (Andersson et al. 2020). Equipped with phones with the pre-installed application, and with paper-based manuals for GPS measurement and application use (Andersson & Kilakila 2020), extension workers provided advices to any interested maize growing farmer in their respective operational areas in Momba and Mbozi districts (Figure 1). They were given a target of 35 advices per extension worker, and no other selection criteria than the farmer's interest to receive advice for a field on which they planned to grow maize.

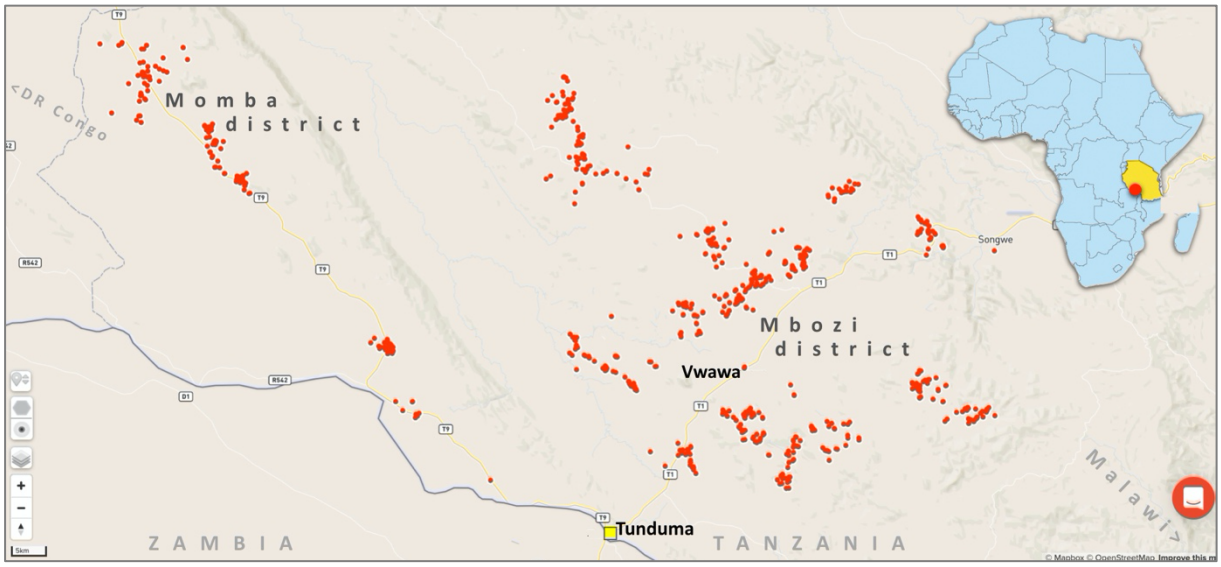


Figure 1: MNM-advices provided by 33 government extension workers in Songwe region (n=1038)

On average, 31 MNM advices were provided per extension worker (max. 45, min.2) in a period of less than 2 months. As Table 1 shows, the majority of extension workers were men, which probably reflects a larger overall number of male extension workers in the two districts. While gendered differences in ownership and experience with smartphones may be an alternative reason for the uneven distribution, there is no indication this played a role; of the 9 extension workers (27%) who had the MNM application installed on their own smartphone, more than half (n=5) were women.

Table 1: MNM advice providing government extension workers in Mbozi and Momba districts for the 2019-20 maize growing season.

	Women	Men
Mbozi district	11	17
Momba district	3	2
(33=100%) **TOTAL**	14 (42%)	19 (58%)

While 42% of the extension workers were women, the vast majority (n=742) of advised farmers were men (71%). This is, however, not necessarily an indication of selection bias on the part of extension workers. That more men received MNM-advice may be the result of women farmers registering their husbands in MNM as they do not consider the field to be theirs, do not own themselves a phone, etc. A participatory evaluation of MNM use (planned for early 2021) may provide more insight into this higher number of male farmers being registered as MNM advised farmers.

2.2 Types of fertiliser advice provided

Since DAP and Urea are the cheapest and most widely used sources of Nitrogen (N) and Phosphorus (P), MNM-advices are built on these two nutrient sources. No Potassium (K) recommendation is provided as it is generally regarded as not limiting in the soils of the Southern Highlands; hence, there is no recommendation for K in the standard (blanket) government nutrient recommendations for maize. MNM only provides NPK-fertiliser advice when the farmer has observed K-deficiency in his/her maize crop in the same field in the previous season (hence only when no crop rotation is practised). The MNM application, as well as the Farmer Advice Forms

Although MNM advice is based on the cheapest source of N and P, farmers may also indicate they prefer to use other top-dressing fertiliser(s) than Urea. Also, farmers who indicate they already have purchased fertilisers receive MNM advice to complement this fertiliser up to the indicated investment level.

Table 2 shows that MNM commonly provides DAP-Urea based fertiliser advice (41%) and that many advised farmers already had purchased (some) fertiliser by the time they received MNM advice (41%). This indicates that many farmers plan the season in advance; field observations suggested that many farmers already purchase (some) fertiliser for the new season when they sell their harvests in July/August and store this fertiliser until the start of the new season.

Table 2: Fertiliser types in MNM advices provided in the Mbozi and Momba districts for the 2019-20 maize growing season.

	# advices	%
DAP + Urea [A1+A4]	427	41
DAP + other N-fertilisers [A2+A5]	109	10
NPK + Urea [A7+A10]	58	6
NPK + other N-fertilisers [A8+A11}	20	2
Additional fertilisers [A3+A6+A9+A12]	424	41
TOTAL	**1038**	**100**

(A1 to A12 refer to specific advice types)

2.3 Types of Management advice provided

Fertiliser management advice provided by MNM is based on farmers' past management practices in the same field; consequently, only farmers who cultivated maize in the MNM advice field in the 2018-19 season (n=340), received field-specific management advice for maize for the 2019/20 season. All other farmers received more general management advice, including the advice to use manure regularly and at/before planting, to use P-containing fertilizers at planting and N-only (top-dressing) fertilisers only after planting, and to split top-dressing fertiliser use (if above 25 kg/ha), etc.

Table 3 gives an overview of some of the field-specific management advices provided. As all farmers were asked whether they use manure on the field regularly and in the previous (2019-20) season, all MNM advised farmers received advice on manure use (see also chapter 3). While limited (regular) use of manure most likely signifies smallholder maize growers' resource constraints and/or preferential use of manure to other crops than maize, many maize growing farmers who planned not to crop rotate, observed nutrient deficiencies in the maize in the 2018/19 season (table 3). These farmers were specifically advised to apply manure this season, and to apply more P fertilisers or NPK fertilisers.

Table 3: Some types of field-specific fertiliser management advice provided for the 2019-20 maize growing season

	# advices	%
No manure applied (regularly) to the field (n=1038) '**Try to apply manure before/at planting'**	824	79%
Observed P and/or K deficiencies in maize (n=340) '**Try to apply manure before/at planting'**	135	40%
No BASAL fertiliser applied in maize field (n=340) '**Try to apply BASAL at planting'**	47	14%
Late applied BASAL fertiliser (after planting) (n=340) '**Try to apply BASAL (NP[K] fertiliser) at planting'**	36	11%
Applied 1st TOP dressing at tasselling or silking (n=340) **'Apply 1st TOP latest when maize has 8-10 leaves'**	30	11%

Of the (n=340) farmers who cultivated maize on the MNM advice in the 2018-19 season, 14% indicated not to have used any fertiliser at planting. Since few farmers apply manure (regularly), this means that about 11% of maize growing farmers did not replenish the Phosphorous off-take resulting from maize cultivation in the 2018-19 season. Another 11% of maize growing farmers used NP(K) fertilisers after planting, at crop emergence or later. They were advised to apply such fertiliser at planting, in order to improve the uptake of P from this fertiliser.

Late application of the first top-dressing fertiliser (11%) is another practice that MNM picked-up, and which resulted in the MNM-advice for farmers to start applying top-dressing fertilizer earlier (preferably 1st application at 5-6 leaves). An analysis of yields and targeted interviews with farmers who late apply top-dressing fertilisers could provide insights into the possible drivers of this practice, such as financial or labour constraints, or no apparent N-deficiencies being observed by the farmer during the season.

3. MNM data collection: Field conditions

MNM collects the following data in the maize fields' field conditions: its size (by GPS measurement), the field's slope, the field's position in the landscape, and the field's soil texture. The latter three variables are visually assessed by the extension worker and the farmer (Figure 2).

Figure 2: MNM input screens for (GPS based) field measurement, field slope, landscape position and soil texture assessment

3.1 MNM field sizes

MNM advice fields are generally small. Average field size is 0.52 ha (max 4.8, min. 0.04; n=989), and 89.9 percent of the fields are smaller than 1 hectare. Maize fields smaller than 0.5 hectare predominate: 67.7 % are < 0.5 hectare. (Note that fields smaller than 0.04 hectare cannot be measured, and 4 fields larger than 5 ha are excluded due to suspected measurement errors).

Field size constitutes a key variable in the MNM application, as it is the basis for seed quantity purchase requirements and fertiliser input per ha estimations (and yield estimations). Earlier research has shown that smallholder farmers have difficulty estimating the size of fields (Carletto et al. 2013, Kilic et al. 2013); consequently, estimating the required amounts of inputs (fertilisers, seed) become problematic.

3.2 Field slopes, landscape positions and soil texture

Figure 3 provides an overview of the field conditions of the MNM advice fields. The findings seem in accordance with the general features of the landscape on the Mbeya plains, on which both Mozi and Momba districts are located. Further analyses – requiring yield data – are needed to identify whether these field conditions are important determinants of yields in the area.

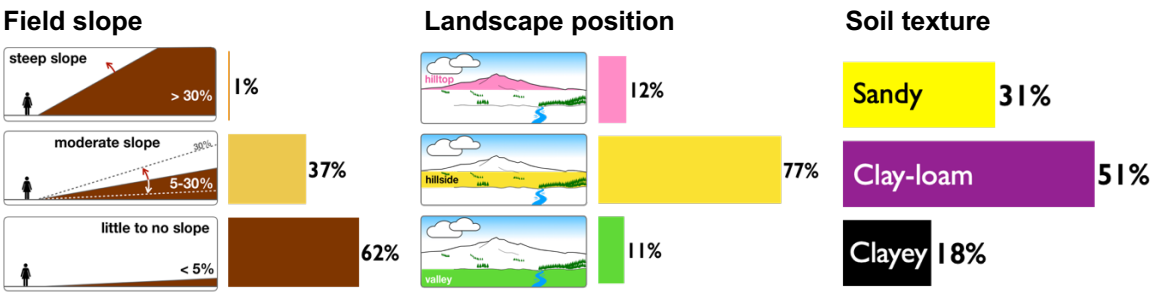


Figure 3: Field conditions recorded by Maize-Nutrient-Manager in the 2019-2020 season (n=1038)

4. MNM data collection: Farmer management

Farmers' (past) management practices not only form the basis for MNM advisory, they are also key in shaping NUE and yields. Therefore, MNM data collection concentrates on field management data. After collecting data on field conditions – such as slope and soil texture – that shape nutrient availability, a first focus in MNM's collection of management data is on manure use, the only source of nutrient inputs farmer use, next to artificial fertiliser.

Figure 4 shows that few farmers ever apply manure on the field they seek MNM-advice for. About 20% (in)frequently applies manure, and less than half of these farmers applied manure on the MNM field in the 2018-19 season.

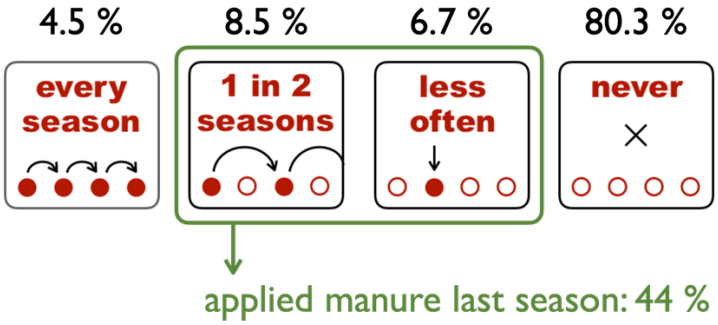


Figure 4: Reported manure use on the MNM-advice field (n=1038)

Management data collection in MNM currently concentrates on collecting management data on maize cultivation, as this is the basis for advice generation. As about one third of advised farmers (n=340) sought MNM advice for a field on which they had cultivated maize in the 2018-19 season, farmer management data collected largely pertains to this sub-group. The vast majority of these farmers (29.5%) cultivated maize as a sole crop (table 4). Only 2.2% of farmers cultivated maize an intercrop.

Table 4: Crops grown on the MNM-advice field in the previous (2018-19) season (n=1038)

	%
Maize	29.5
Beans	27.8
Groundnuts	13.6
Sunflower-groundnuts	8.3
No crop (fallow)	7.3
Other crop	3.2
Maize intercropped	3.1
Other crops combinations	7.2
TOTAL	**100**

All maize growing farmers of the 2018-19 season were asked detailed questions about their cultivation practices on the 2019-20 season MNM advice field. These included:

4.1 Land preparation and seeding practices

- Maize variety (type) grown
- Use of recycled seed (Y/N)
- Kilogram seed used (kg)
- Planting method (n=340) (53.2% handhoe, 44.7% sowing while ploughing)
- Time of planting (n=322): before the rains (7.3%), with the 1st rains (61.5%), 3+ weeks after 1st rains (22.4%), don't remember planting time (6.8%), on a particular data (2.8%)

Figure 5, which shows commonly used maize varieties, suggests that 15.6% of farmers used open pollinated, local maize varieties. Seed recycling – re-using the grain of harvested hybrids as seed – also appeared to be a fairly common practice, roughly in the range of 0-28%, depending on the hybrid maize variety used.

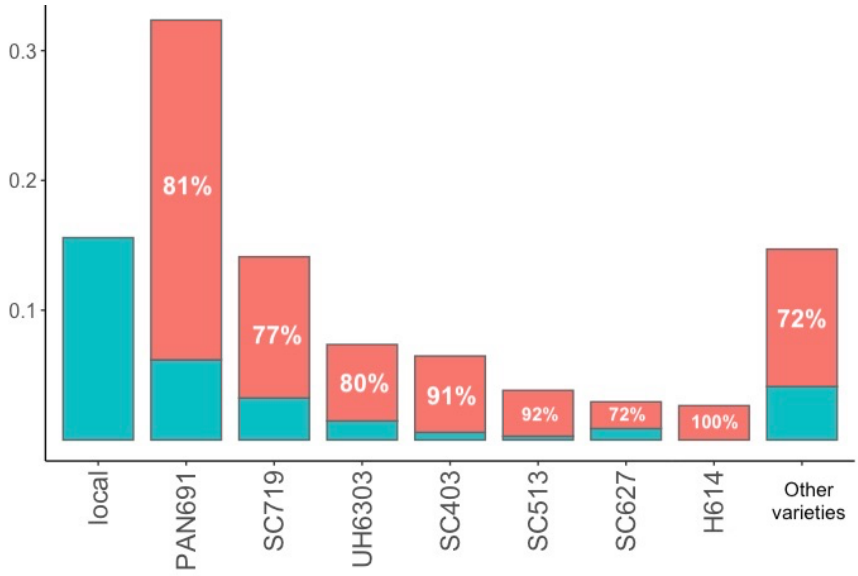


Figure 5: Share of most commonly used maize varieties and percentage of newly bought seeds (red bars), 2018-19 season (n=340)

Initial analyses of planting densities of the most commonly grown (recycled) hybrid varieties suggest there is neither a relation between field size and planting density, nor between hybrid variety type and planting density or the recycling of hybrids and planting density.

Table 5: Planting densities (seeds/ha) for the 7 most commonly grown (recycled) hybrid maize varieties in the 2018-19 season (for fields < 5 ha), n=207

Min.	1st Quan.	Median	Mean	3rd Quan.	Max.
8076	35623	45468	45194	54162	89103

4.2 Fertilizer use – at planting

- Types and quantities used at planting (n=340):
  DAP (83.8%), other (2.4%), no fertiliser used (13.8%)
- Method of application at planting (n=340):
  below/next to seed (55.8%), broadcasting (1.5%), placement-when-ploughing 28.8%), no fertiliser used (13.8%)

Maize growing farmers appear to have applied relatively low rates of P-fertiliser to their maize in the 2018-19 season. While some farmers (13.8%) of farmers apply no fertiliser at all at planting, half of those who do, applied 25 kg P/ha (average 26.8 kg P/ha, std.dev. 10.7), which is more than the (blanket) recommendation of the Tanzanian government (20 kg P/ha) (Table 6). Figure 6 shows horizontally arranged 'lines' of observations at 5, 10, 15 and 20 kg P/ha, which represent respectively 0.5, 1, 1.5 and two 50kg bags of DAP, the predominantly used fertiliser source of P.

Table 6: Fertiliser use at planting among farmers who used P-fertiliser at planting in the 2018-19 season (for fields < 5 ha), n=261

Min.	1st Quan.	Median	Mean	3rd Quan.	Max.
2.13	20.92	25.16	26.80	32.30	72.56

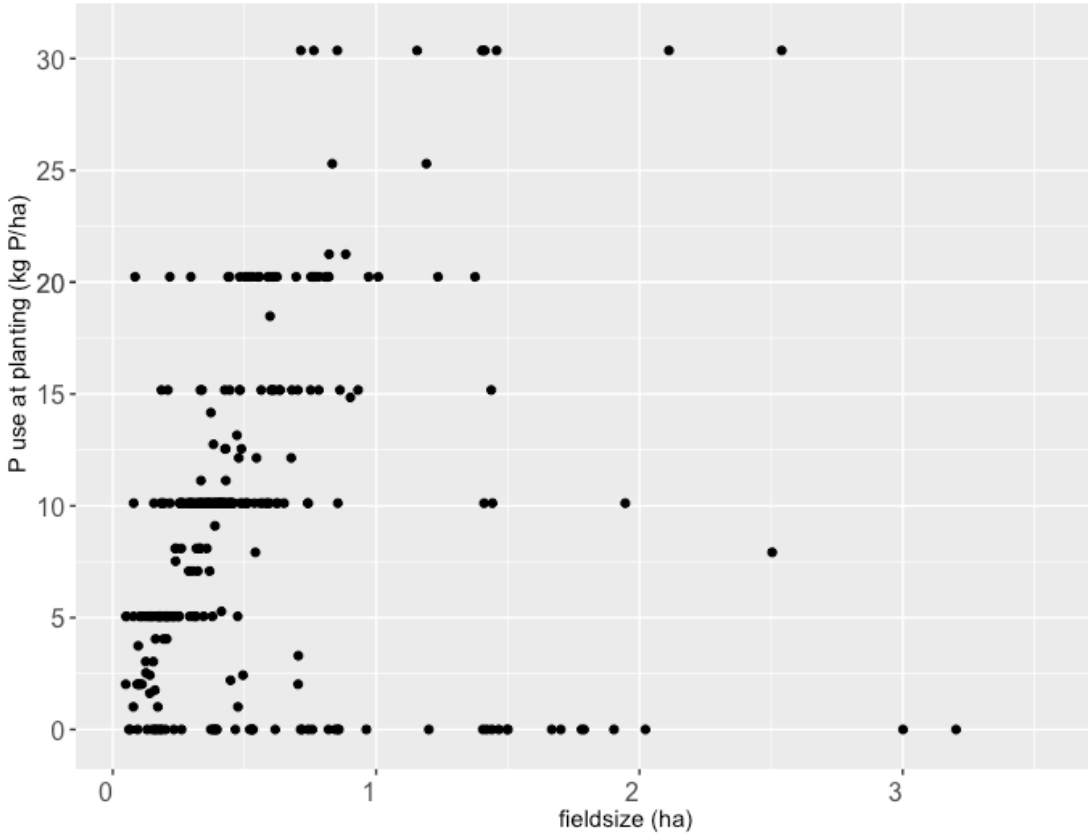


Figure 6: P use at planting (kg P/ha) in the 2019-20 season (n=308)

4.3 Fertilizer use – after planting

- Types, quantities and timing of application after planting (n=340):
  At first top-dressing application: Urea (64.8%), SA (8.3%), other type(s) (16%), none (10.9%)
  At second top-dressing application: Urea (19.2%), CAN26 (9%), other type(s) (7.7%), none (64.1%)
- Method of application after planting (n=340):
  broadcasting (34.1%), dibble (12.1%), next-to-seed(42.9%), no fertiliser used (10.9%)

While slightly more maize growing farmers (n=340) applied (top-dressing) fertilisers after planting (89.1%) than at planting (86.2%) in the 2018-19 season, some 8.5% did not apply any fertiliser at all. A majority applied (a mix of) top-dressing fertilisers only once (53.2%), 34.1% applied such fertilisers twice.

Table 7 shows that farmers who do use N-fertilisers (n=301), on average use 108 kg N/ha, which is slightly less than the standard (blanket) recommendation of the Tanzanian government (120 kg N/ha). However, average use has little meaning, as N-input per hectare varies enormously (Figure 7). There is a tendency for N-input to decrease with the size of the MNM field cultivated to maize.

Table 7: Total N use among MNM-advised farmers who cultivated maize on the MNM-field ibn in the 2018-19 season (for fields < 5 ha), n=273

Min.	1st Quan.	Median	Mean	3rd Quan.	Max.
4.88	75.49	103.6	108.1	139.2	270.9

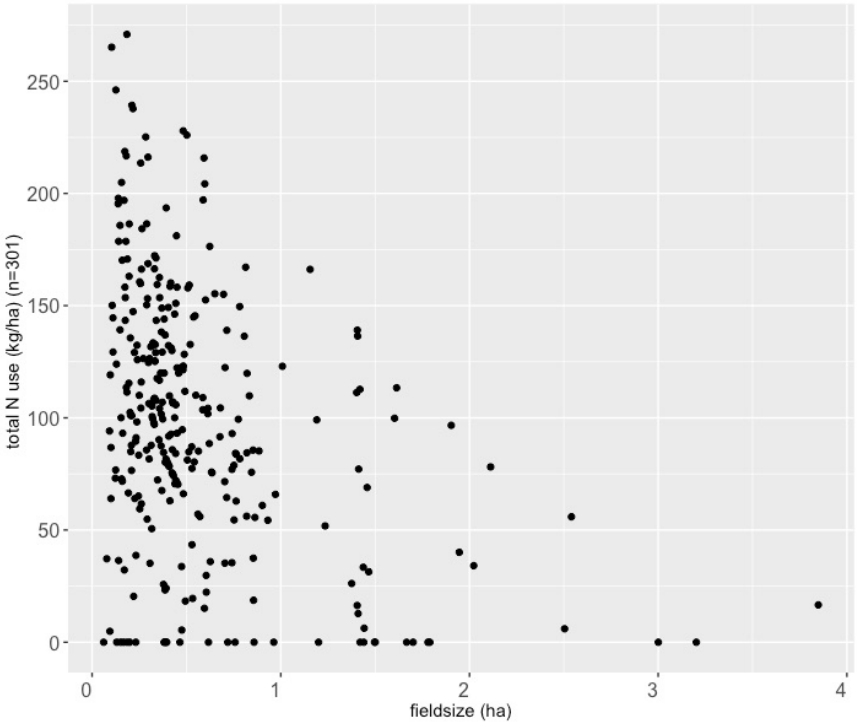


Figure 7: Total N use (kg/ha) for maize growing farmers in the 2018-19 season (n=301) (fields <5 ha, N use: <300 kg/ha)

4.4 Observed nutrient deficiencies in maize

- P deficiency: 12.4%
- K deficiency: 7.4%
- P + K deficiency: 20%

4.5 Herbicides use and weeding practices (n=340)

- pre- emergence herbicides use: 43.5%
- post-emergence herbicides use: 25%
- number of weedings: no weeding (19%), One time(25%), twice (52%), three times (4%)

4.6 Yield

- Harvest from the field (measured in *gunia* @ 110 kg)
- Harvest of field kept separate from other maize field(s)? *Kept separate (46.8%)*
- Did you use a shelling machine at harvest? *Use of sheller at harvest (67.4%)*
  (the last two variables are used for data quality assessment)
- Observed pest and disease prevalence (to assess possible effects on yield):
  No effect on yield (42%), little effect on yield (43%), yes, and reducing yield (14%)

Descriptive statistics in Table 8 show the large variability in yields maize growing farmers obtained in the 2018-19 season.

Table 8: Maize yields (kg/ha) on MNM-fields in the 2018-19 season
(for fields < 5 ha, yields <10t/ha), n=296

Min.	1st Quan.	Median	Mean	3rd Quan.	Max.
198	1931	3242	3418	4749	9444

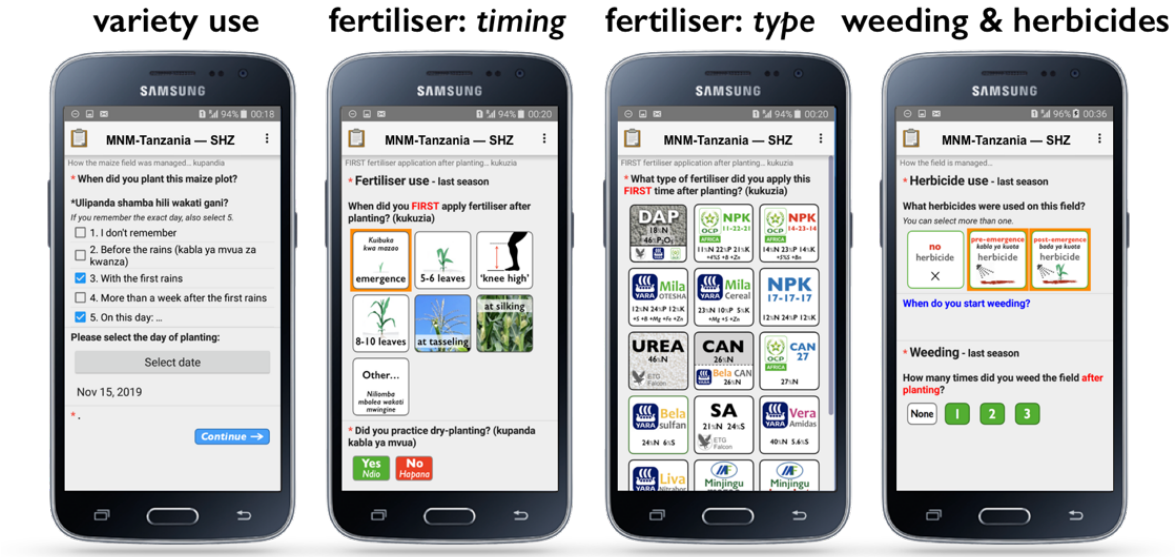


Figure 8: Examples of field-level management data recorded in Maize-Nutrient-Manager

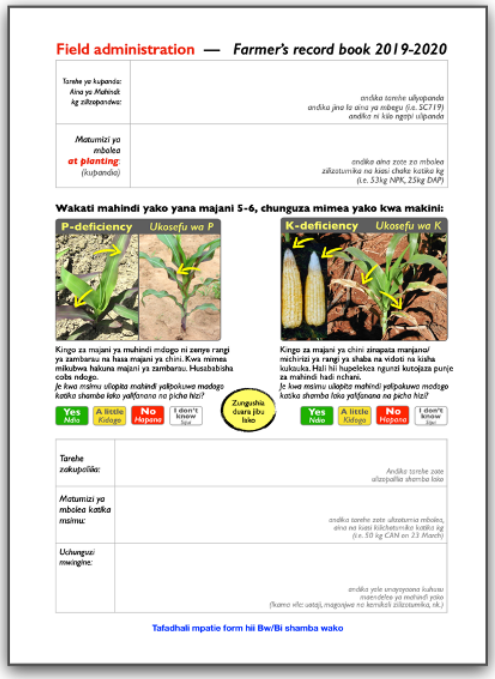
5. Farmer management records and MNM use in 2020-21 season

In order to facilitate farmer use of the *app*-generated MNM advice, advices were written on Advice Forms (AF) and handed to farmers. Farmers were asked to record their management of the MNM-field on the backside of these forms – the Field Record sheet (FR) – as illustrated in Figure 9.

Number of MNM advised farmers:	**1038**
Number of returned Farmer record sheets:	**790**
Matching[1] MNM-advices – record sheets (n):	**723**

Data collected through Farmer Record RFR) sheets:

- Date of MNM advice provision, date of planting
- Manure use on MNM field 2019-20 season
- Maize variety + kg seed planted
- Fertiliser use at planting (types, quantities)
- Observed deficiencies in maize: P, K
- Date of first, second, third weeding
- Date of 1st fertiliser application after planting (+ types, quantities)
- Date of 2nd fertiliser application after planting (+ types, quantities)
- Date of 3rd fertiliser application after planting (+ types, quantities)
- Effects of Pest & diseases on yields
- Seed emergence
- Other observations


Field administration — Farmer's record book 2019-2020

Wakati mahindi yako yana majani 5-6, chunguza mimea yako kwa makini:

P-deficiency Ukosefu wa P

K-deficiency Ukosefu wa K

Yes Ndio | A little Kidogo | No Hapana | I don't know Sijui

Zungusha duara jibu lako

Tafadhali mpatie form hii Bw/Bi shamba wako

Figure 9: Farmer Record sheet as used by MNM-advised farmers in 2019-20 season (n=753)

Collection of Field Record data was hampered by travel restrictions caused by COVID19, but TARI-Uyole managed to mobilize extension workers and collect a substantial number of Field Record sheets – n=723 of these could be matched to MNM-advices provided through the *app.*

The quality of farmer record keeping is, especially in this initial year of advice provision, difficult to assess. Nevertheless, virtually all recording farmers (n=723) recorded the day of planting (99%), and 95% recorded the maize variety used during the 2019-20 season. Fertiliser use recording was equally promising, as 97% of farmers specified what type(s) of fertiliser was used at planting (*DAP: 92%, NPK(S): 5%, no fertiliser used (3%).* This suggests that MNM advised farmers were more likely to use fertiliser at planting in the 2019-20 season, then they had in the 2018-19 season, when 13.8% (n=340) reported not to have used fertiliser at planting on the same MNM field cultivated to maize.

[1] Matching of MNM advices and Farmer Record sheets was done on the basis of: farmers name, mobile phone number, district and ward, and recorded GPS-measured size of the MNM field. As farmers often spelled their names in multiple ways or changed their phone number, matching on the basis of these two variables alone is insufficient. Only when also the difference in the MNM-measured field size and the recorded field size on the Farmer Record sheet was <0.1 ha, the advice and recorded sheet were considered a match.

5.1. Yield data collection for 2019-20 season and MNM use in 2020-21 season

The follow-up of MNM-advised farmers during the 2019-20 season has been severely hampered by COVID-19 travel restrictions. Also participatory user evaluations of the MNM *app* were not possible and had to be postponed until 2021. Nevertheless, it has been possible to training nearly 50 extension workers in the use of an updated version of MNM (app version2) in November 2020.

As MNM trained extension workers who also participated in the 2019 pilot have been instructed to preferentially revisit the MNM advised farmers of the 2019-20 season, it is expected that more data on the 2019-20 season will be collected. As MNM advisory is based on past management and yields, it is expected that 2020-21 and MNM advice provision will yield additional data on field management and yields obtained in the MNM fields of 2019-20 season. A full analysis of MNM advisory in the 2019-20 season is therefore only possible after MNM advice provision for the 2020-21 season have bene completed in early 2021.

6. Acknowledgements

We thank our collaborators of the maize team, Boniface Minja, Leonard Sabula and Gregory Bundala at the Tanzanian Agricultural Research Institute at Uyole (TARI-Uyole), for organizing the logistics, workshops and support of the fieldwork.

7. References

Andersson, J.A. and Kilakila, M. (2020) Maize-Nutrient-Manager: Training workshops, Songwe regions, Tanzania. Wageningen, The Netherlands: CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS). www.cropnutrientgap.org (https://cgspace.cgiar.org/handle/10568/110706)

Andersson, J.A., R. Hijbeek, T.S. Sida, M. Kilakila (2020). Maize-Nutrient-Manager: A mobile phone application for field-specific, balanced nutrient management advisory, 30 p. www.cropnutrientgap.org (

Carletto, C., Gourlay, S. and Winters, P. (2013) *From Guesstimates to GPStimates: Land Area Measurement and Implications for Agricultural Analysis* (Policy research working paper 6550) (pp. 1–29). Washington DC: World Bank.

Kilakila, M. 2020. *Laying the foundation of the Maize-Nutrient Manager (MNM) mobile phone based application the Southern Highlands of Tanzania.* Internship report, CIMMYT / Plant Production Systems group, Wageningen University.

Kilic, T., Zezza, A., Carletto, C., and Savastano, S. (2013) *Missing(ness) in Action: Selectivity Bias in GPS-Based Land Area Measurements* (No. Policy research working paper 6490) (pp. 1–31). Washington DC: World Bank.